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Simple Implementation of an Electronic Tongue for Taste Assessments of Food and Beverage Products

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Abstract: Although the electronic tongue (e-tongue) was first introduced more than 20 years ago, the few commercial versions available today are rather expensive. This paper demonstrates an easy approach to the implementation of a laboratory e-tongue capable of discriminating the taste of a number of food and beverage products, by integrating readily available commercial parts. This e-tongue was implemented on a PC by interfacing an array of chalcogenide-based potentiometric sensors with a Silver/Silver Chloride reference electrode, data acquisition module and controlled/analyzed by the ubiquitous MATLAB software. Two graphical user interfaces (GUI) developed in MATLAB environment are presented to demonstrate easy control of the e-tongue and its analysis. The data acquired from experiments were subjected to statistical analysis and the performance of this instrument is presented in Principal Component Analysis (PCA) plots. These results show that the relatively simple e-tongue can effectively discriminate the tastes of the various agro-products. *Copyright © 2011 IFSA.*

Keywords: Hardware taste sensor, Electronic tongue, Design of e-tongue, Qualitative, Quantitative.

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1. Introduction

The demand for agro based products to be of consistent quality has long been in place. With consumer these days getting more particular, the need to ensure a replicated quality of produce is on the rise. Yet more than often, agro based raw materials differ seasonally and geographically which led to some variations in the quality of the produce. Hence this would require a panel of trained professional taster or expensive laboratory equipment (e.g. HPLC) to verify each batch of raw material as well as end product. Both ways are either labor intensive or expensive.

Since the first work on multi-sensors array in 1985 [16], a variety of technology for e-tongue has emerged. Test results has shown promising potential in the area of food and beverages, pharmaceutical and environmental monitoring [6, 9, 18]. Nevertheless, comparison between progresses made by e-tongue is much less than that of the electronic nose (e-nose). Moreover, commercially available e-tongue is just a handful with very steep pricing. Continuation on our study on microcontroller based e-tongue [10], now in this paper we present how to implement a relatively low cost e-tongue on a PC using 'off-the-shelf' hardware and software. The use of graphical user interfaces (GUIs) allows easy operation for non technical users in data collection, signal conditioning and data analysis. This user 'friendly' system may serve as a useful tool to facilitate the study of e-tongue and its application in agro based industries.

2. Experimental

A taste sensing system (e-tongue) is an instrument with capabilities similar or even better than the human tongue. Sensing electrodes as taste buds excite in the presence of taste chemicals, triggering new potential difference as compared to reference electrode. Sensors response treated as a pattern of taste sent to the processing (intelligence) unit for taste measurement, identification and future classification.

The implementation of this instrument consist of three major parts; the sensors, sensor interface and processing unit. Additionally, graphical user interfaces developed as a means to ease control and analysis of the tongue and its data for frequent use. Simplified block diagram of this instrument and its implementation shown in Fig. 1 and Fig. 2 respectively.

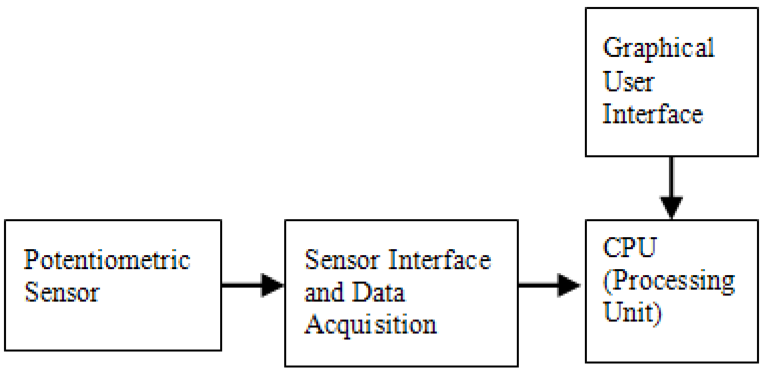


Fig. 1. Basic e-tongue configuration.

2.1. System Overview

A number of chemical sensor options which had been reported in works on e-tongue include potentiometric (lipid membrane electrodes [10, 13, 14], chalcogenide glass electrodes [6, 16] and PVC plasticized membrane electrodes [15]), voltammetry (rare metal electrodes [18]), impedentiometric (composite sensor [9] and conducting polymer [11]). Among all, potentiometric measurement is the simplest and naturally, Chalcogenide glass sensors were chosen for its availability.

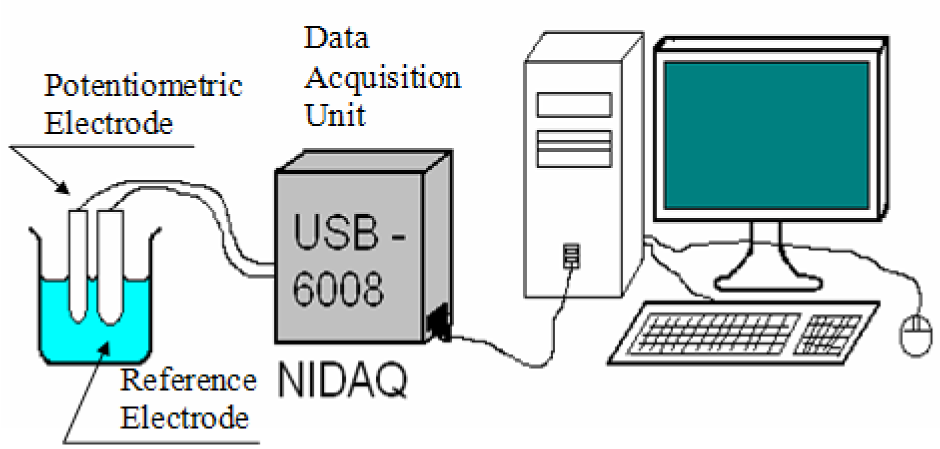


Fig. 2. E-tongue system implementation.

The taste electrode is made up of an array 7 chalcogenide glass membrane sensor. These potentiometric sensors are ion-selective sensors [5] for Mercury ions (Hg^{2+}), Cadmium ions (Cd^{2+}), Titanium ions (Ti^{+}), Iron ions (Fe^{3+}), Copper ions (Cu^{2+}), Chromium (IV) ions and Sulfur ions (S^{2-}). The development of this artificial taste sensor exploits the reduced (wide) selectivity of chemical sensor to obtain response from complex aqueous solution. By using an array of variable chemical sensors, a pattern of response can be obtained and with the aid of suitable statistical tools, this pattern of response may be classified [16]. Together with the above mentioned electrodes is a Silver/Silver Chloride electrode which acts as a reference electrode to all the chalcogenide sensors. This easily available
off-the-shelf product acts as a redox electrode [12].

Potentiometric sensors employed in the realization of this simple instrument responded by exhibiting steady state voltages upon being dipped into test solutions. Electrode's internal impedance varies to as high as 10 kOhm [5] and the National Instrument's data acquisition unit USB-6008(NIDAQ) conformed to these requirements by having an input impedance of 144 kΩ and is capable of sampling up to 10k samples per second for up to 8 channels simultaneously. Working at maximum voltage limits of ±10Volts will give a resolution of 9.766 mV [8].

The PC is the obvious choice for the e-tongue platform. In this case, a Pentium 4 running under Microsoft Windows XP was used together with a mathematical software package, MATLAB. Although it is possible to write software codes for the PC to control the e-tongue and perform the statistical analysis, it is rather tedious, particularly for the non-computing personnel. Fortunately, MATLAB offers the opportunity to access hardware, customize and hide codes behind a Graphical User Interface (GUI). The MATLAB used in the duration of this study is MATLAB R2008a version 7.6.0.324.

GUIs were developed as part of the effort to ease the control of the e-tongue. Its employment hides away programming codes replacing them with an interface window. Two GUIs were developed for this purpose with the first being a GUI to facilitate the control of the data acquisition processes. This DAQ-GUI as shown in Fig. 3 allows the user to operate NIDAQ from the MATLAB environment. Sampling time, frequency and storage location is user defined. The second GUI developed to ease the PCA analysis of multiple data of up to 10 different data files. Also built-in into this GUI are functions for data filtering, cropping and merging. The requirements for other processing and analysis such as artificial neural networks (ANN) at a later stage can readily be accommodated by the numerous MATLAB Toolboxes.

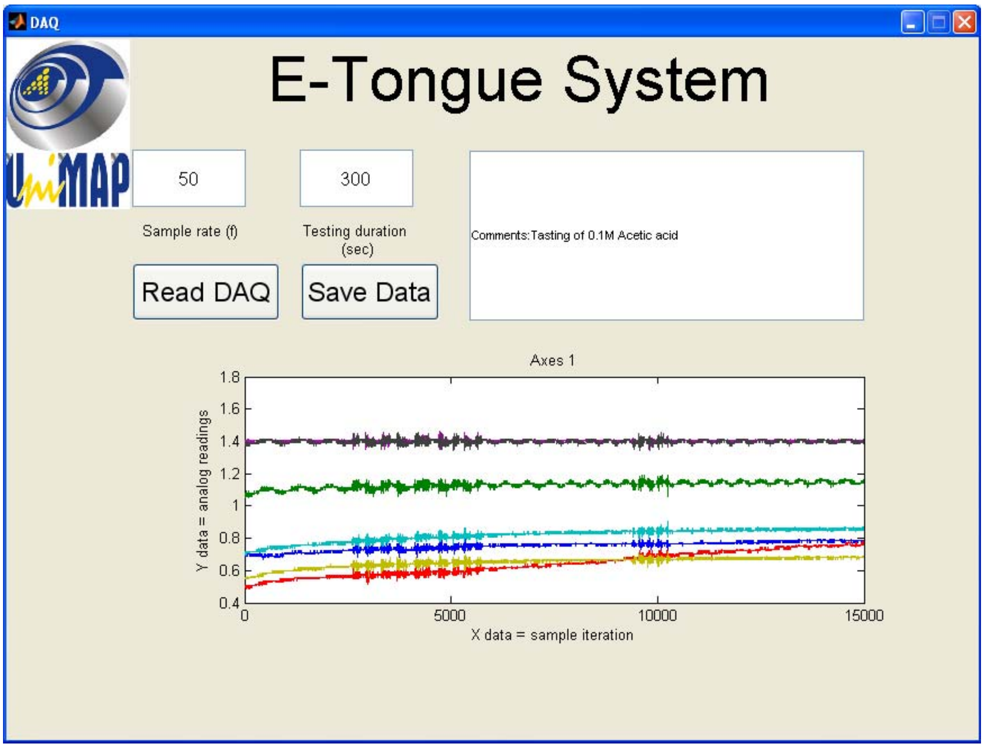


Fig. 3. Data acquisition GUI interface.

2.2. System Test

Taste is comprised of five basic qualities which can be used to 'calibrate' an e-tongue [13]. In previous reported work, various chemical and organic compounds were used to represent these basic tastes [9, 14].

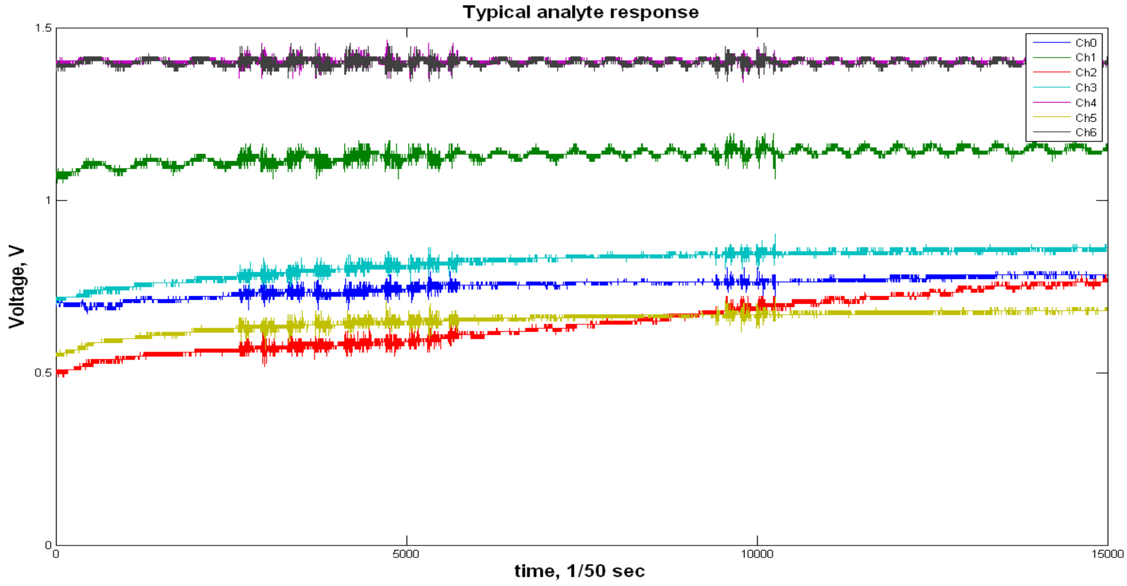
In this work, the basic taste samples were represented by Sodium Chloride (NaCl) for saltiness, Magnesium Chloride ($MgCl_2$) for bitterness, MonoSodium Glutamate ($C_5H_8NNaO_4$) for deliciousness (umami), Acetic acid($C_2H_4O_2$) for sourness and Lactose ($C_{12}H_{22}O_{11}$) for sweetness. Table 1 shows the concentration of each basic taste prepared using testing grade chemicals.

Table 1. Summary of taste solution, chemical compound and concentration.

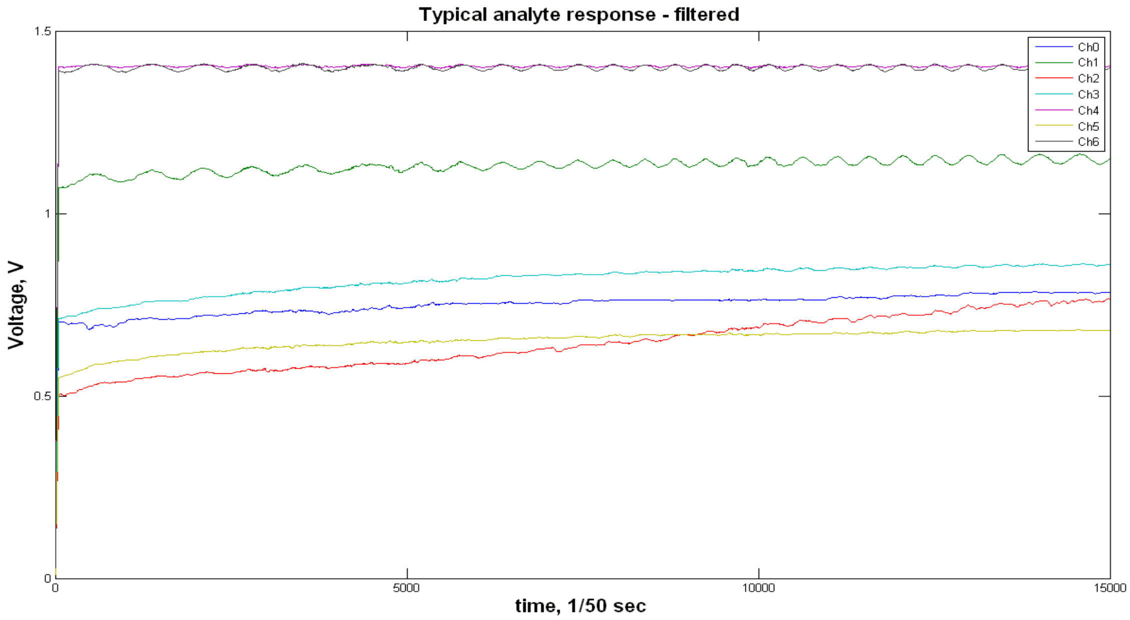
No	Taste Quality	Chemical Compound	Concentration
1	Salty	Sodium Chloride	100 mM
2	Sweet	Lactose	100 mM
3	Bitter	Magnesium Chloride	100 mM
4	Umami	Sodium L-Glutamate	100 mM
5	Sour	Acetic Acid	100 mM

Noise, outliers and redundant signals are the three categories of noise to be removed from raw data. As the nature of response from chalcogenide sensor is of stable dc voltage, any spiking or sudden change in the signal considered noise, while the responses prior to reaching steady state are outliers. Redundancy refers to pattern of response from all sensors which might occur more than once. In the case of PCA analysis, removal of redundant pattern from a signal increases PCA processing speed without affecting its plot.

Removal of noise executed using moving average filter with 50 samples for each point. Outliers are removed by manually inspecting and cropping filtered data, while redundancies are removed using *unique* (Matlab's code) filter built into the PCA-GUI. Fig. 4a shows a typical response of an analyte while Fig. 4b shows the same dataset after subjecting it to moving average filter.



(a)



(b)

Fig. 4. Array sensors response; a) typical, b) filtered.

2.3. PCA of Basic Tastes

Our simple e-tongue had successfully been tested on 5 basic taste solutions. After subjecting their responses through pre-processing steps, a PCA analysis on the 5 basic taste yields a clear clustering of five localities as shown in Fig. 5.

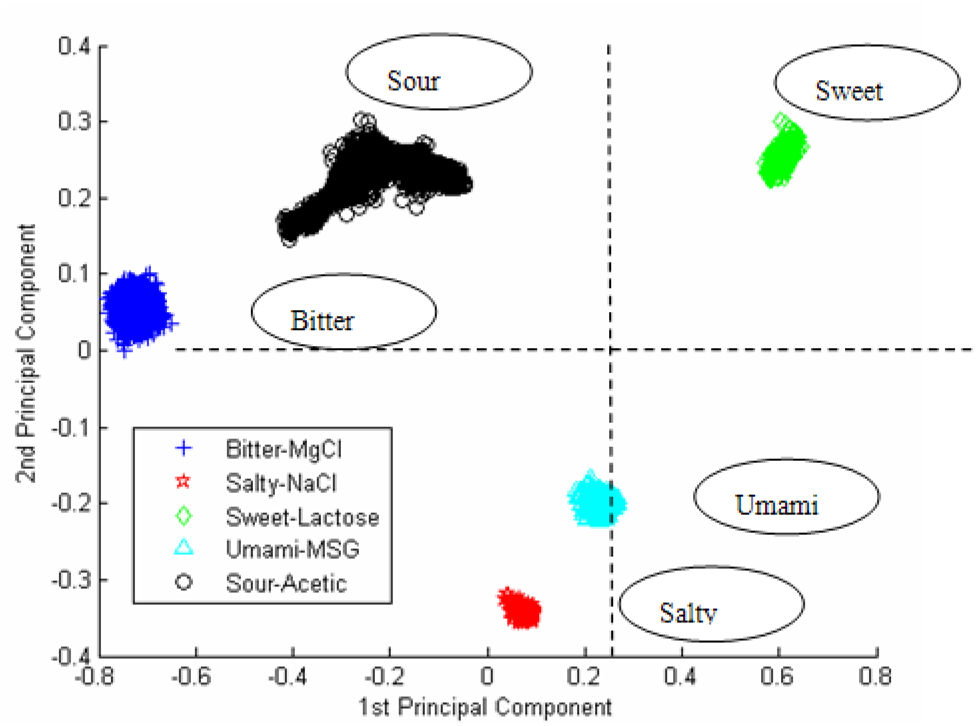


Fig. 5. PCA Classification of Basic Taste.

Fig. 5 displays the 5 locality on PCA graph. The localities is separated where the top right region could be assigned to Sweet-Lactose locality, bottom right region assigned to the Umami locality, Bottom Left region displays to be Salty locality. The Top Left region displays two localities but separated distinctively where on the far left is the Bitter locality and n the far right of the region is the Sour localities. In this paper these regions and localities will be referred as the basic localities in identifying the taste of the Agro-products tested.

A variety of agro-products/produces (honeys, citrus juices, milk fermentation process, teas, rice, honeydew melon and pineapple) were tasted using the e-tongue and had its data subjected to PCA analysis. A global map of these tastes in comparison to 5 basic taste qualities was generated on a PCA plot shown in Fig. 6, the Global Taste Map. Data clustering of tested samples are obvious and do not overlap each other. The clustered data of different agro-products and produce located on the regions or at the nearest regions that resembles the taste of the product as tasted by the human tester.

The PCA plot illustrates that overall the products taste data clustered in the taste region, which is conformant to the human taster decision. The Rice located in the Sweet region, The Cat Whiskas Tea, Honey Dew Melon, Pineapple are in the Umami region but the Cat Whiskas also located near to the sweet region. The Fish Sauce data clustered in two regions, the Umami and Salty with most of the data clustered within the Umami Region. The PCA plot result is comparable to the human taster decision and can confer that this simple e-tongue is relatively capable of ‘tasting’ food. Detail discussion of each tasted sample groups are described below.

2.3.1. Honey

New directive on sale of honey in Europe includes indication of its botanical and geographical [2]. Traditional method in indicating the botanical and geographical origin through pollen identification using microscopic and melisso-palynological requires trained personnel [1]. Identification of honey variations also performed using Alpha MOS's e-tongue [17]. The requirement in indicating the origins and variations of honey and the traditional method used is highly dependable to the knowledge and experience of personnel, point up the potential of an e-tongue in this industry.

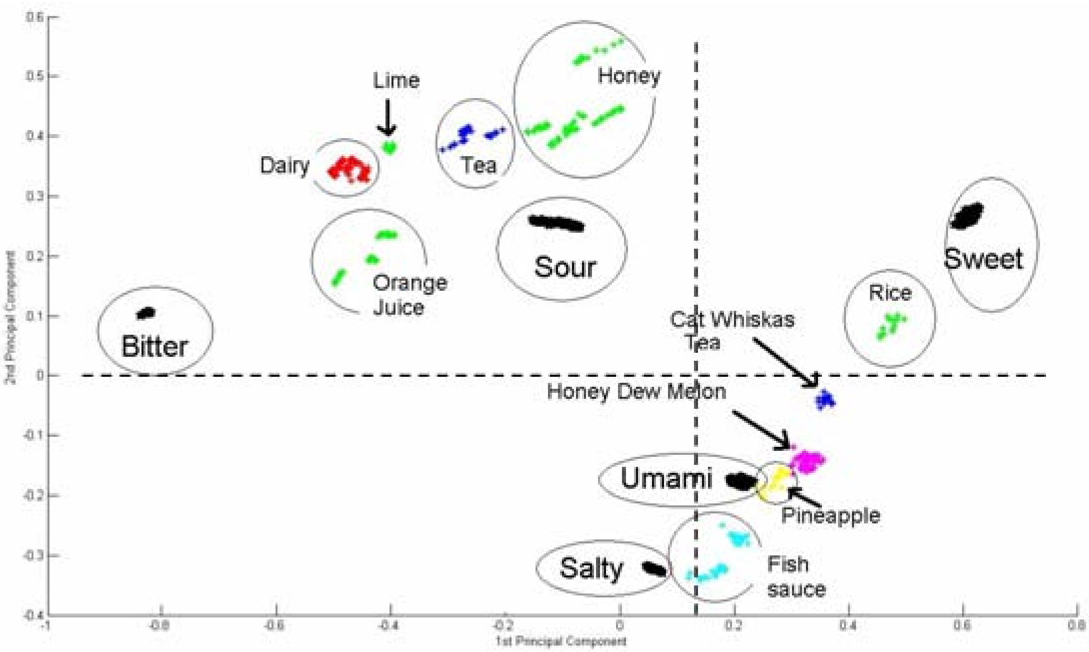


Fig. 6. Global Taste Map.

Five locally available honeys of different floral origin (durian, malaluka, coconut, star fruit and wax apple) acquired and honey test solution was prepared by adding up 10ml of honey to 200 ml of distilled water and was stirred for 300 seconds at 1500 rpm. Upon the test done using the e-tongue, PCA analysis on the honey dataset yields 5 clustering as shown in Fig. 7, which corresponds to honey of 5 different floral origins. On the global taste map, all the 5 honeys group nearby to sour locality with inclination towards sweet locality as shown in Fig. 6. The general human taster confirmed these honeys contain both sweet and sour taste qualities while a digital pH probe(testo) indicates these honey to be acidic(pH 3.8 ~ 4.2).

Within these five floral origins the distributions of the honey data cluster in Fig. 7 demonstrates the varieties of the honey. The result confirmed that the e-tongue could differentiate among the different type of Honey. Referring to the global taste map in Fig. 6, the Durian Honey although in the Sour Region but is the closest to the Sweet region. The other four honey varieties are moderately close to the Sweet Region.

2.3.2. Orange and Lime Juice

Citrus juice is one of the most popular green beverages worldwide. Taste of each individual brand of orange juice differs from one another possibly due to its manufacturing process and also maybe due to its different raw materials.

Taste samples of 3 orange juices from locally available brands and lime juice (200 ml freshly pressed) were prepared in 4 dilution levels as detailed in Table 2.

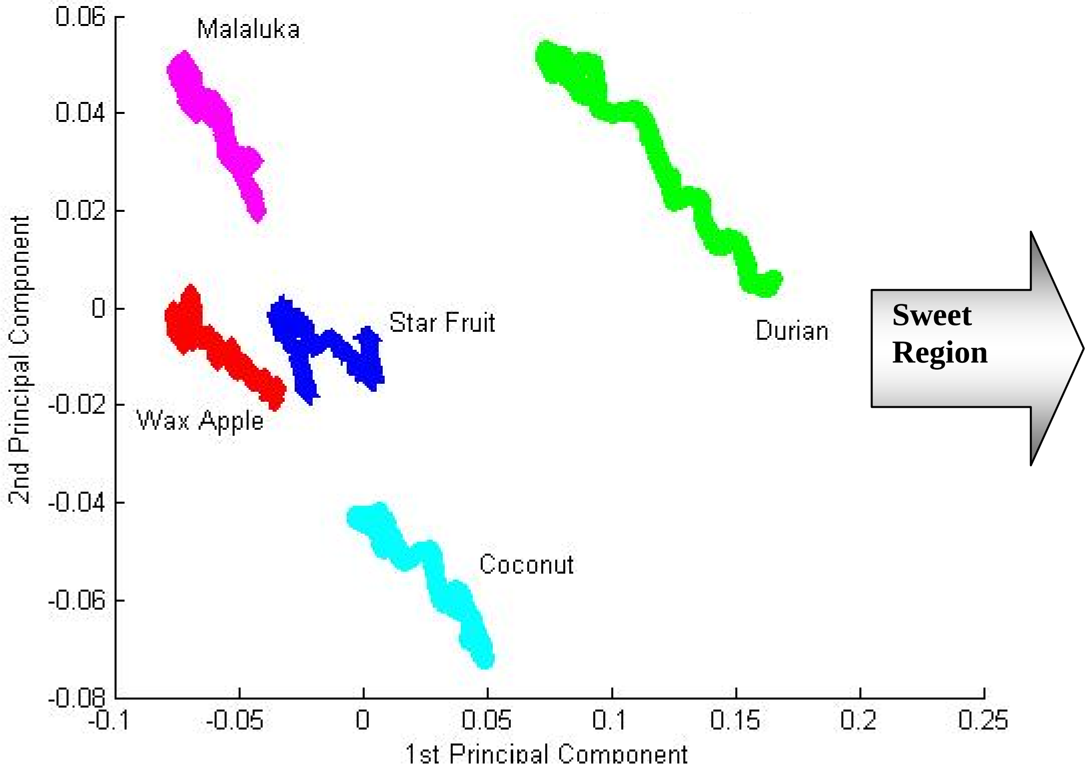


Fig. 7. PCA of 5 Honey variations.

Table 2. Summary of juice dilution.

Pureness (%)	Juice (ml)	Water (ml)
100	200	NIL
75	150	50
50	100	100
25	50	150

The first being pure (100 %) is 200 ml of the original juice, 75 % pure is by adding up 150 ml of juice to 50 ml of distilled water, 50 % pure is by adding up 100 ml of juice to 100 ml of distilled water and 25 % pure is by adding up 50 ml of juice to 150 ml of distilled water.

The PCA plot of these citrus juices indicates the high possibility of both qualitative and quantitative discrimination. On the global map in Fig. 6, citrus juices are seen to cluster into 2 distinctive groups located in sour region. The 1st group make up of lime alone lies nearby sour locality while the 2nd group which consisted all the 3 orange juices lies in between sour and bitter locality. Of the 3 orange juices, brand O3 has the highest inclination towards bitter locality. A general human taster confirms that these juices contain both sour and bitter taste qualities with brand O3 having the highest degree of bitterness, which might explain the bitter inclination.

Since brand O1 and O2 is clustered nearer to sour locality, these brands are selected to be analyzed using PCA to display the relation of dilution level with the closeness to the sour locality. Fig. 8 shows the clustering of citrus juices quantitatively for 2 brands of orange juice with different dilution level. From this PCA plot, PC1 alone is sufficient in discriminating these juices quantitatively. The more diluted juice located at more distance from the sour locality. Although both brands were diluted, the O2 brand might have more sour element since the PCA cluster of O2 (different concentration) display a more dense distribution from 100 % to 25 % dilution.

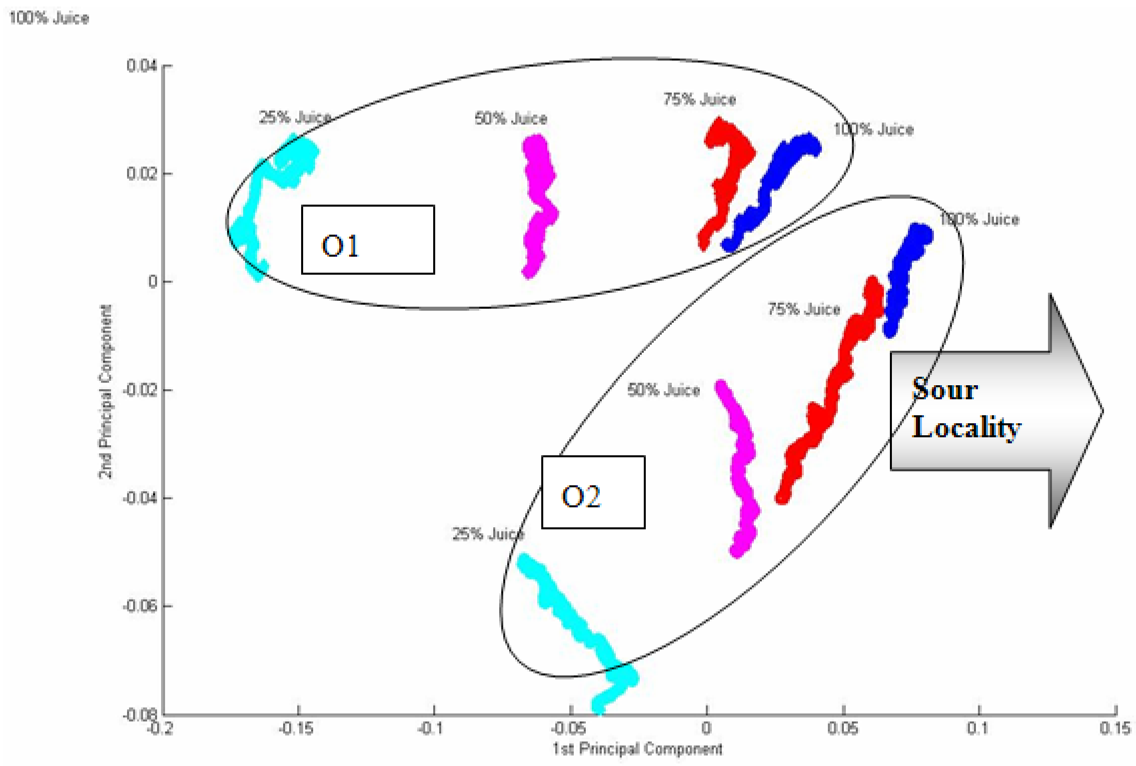


Fig. 8. Quantitative Result – Citrus Juice.

2.3.4. Milk Souring/yogurt Making

Dairy industries exist in almost every corner of the world and works on improving dairy produce qualities using e-tongue had shown promising results [3, 7]. This experiment monitors (intermittently) the process of fermenting milk to yogurt. Samples of 3 milk liquids were prepared by stirring 10 g of full skimmed milk powder to 200 ml distilled water each in separate beakers. 10 ml of yogurt brand Y1 added to the first sample and 10 ml of yogurt brand Y2 was added to the second beaker. All 3 samples were stirred intermittently at 1500 rpm and the liquids were left continuously on top of a 36.0 Celsius hotplate (Harmony) throughout the whole experiment.

Taste sampling done in intervals as the milks change from fresh to sour/yogurt. On the global map in Fig. 6, all dairy samples concentrate closest to sour locality. A zoomed into the PCA of dairy produces alone is as shown in Fig. 9. From this plot, sour milk and yogurt of different brands are distinguishable. The PCA plot also displays the changes of the taste in relation to the incremental of the fermentation time. The e-tongue exhibits ability to differentiate the taste of the dairy product through the fermented time. The PCA displays that the fermented dairies for 15 hours located nearer to the sour locality.

2.3.5. Tea

All over the world, drinking tea has become a way of life for many. Black, green, oolong and white tea are just a few common types of tea in the market. This experiment samples the taste of 4 tea brands (Boh Cameron Highland Tea, Lipton Yellow Label Tea, Sabah Tea and Boh Green Tea) which were prepared by adding up a teabag of 2 g of tea leaves into 200 ml of boiling distilled water and left to cool at room temperature.

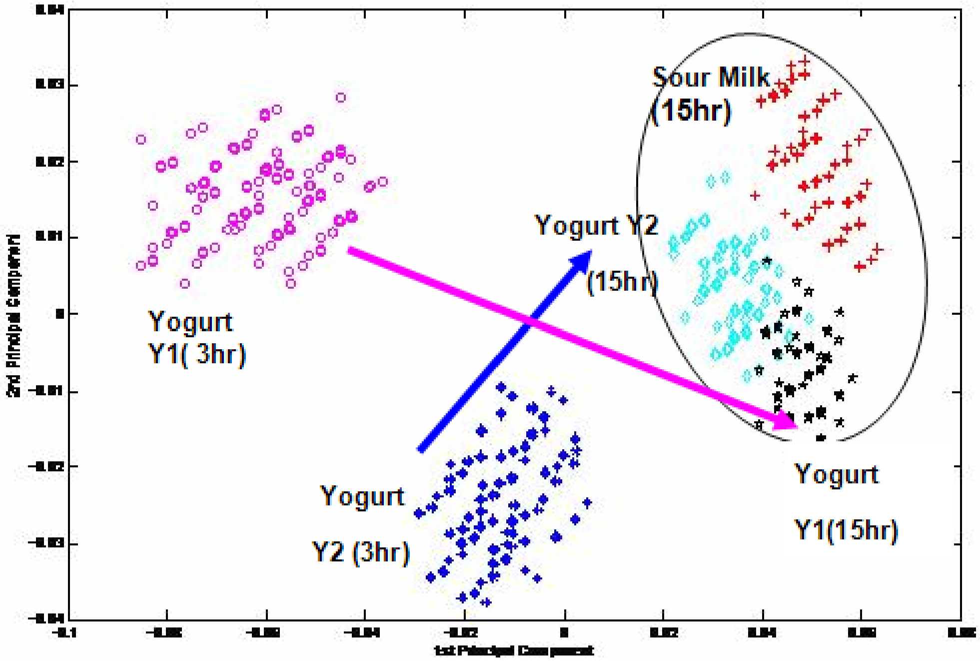


Fig. 9. PCA of milk souring stages.

Subsequently teas of 4 concentration levels were prepared for Lipton Yellow Label Tea brand. Differing concentration levels were made by varying the steeping time of the 2 g teabag in 200 ml boiling distilled water with the time variation being 10, 15, 20 and 30 seconds.

In the global map in Fig. 6, tea data from this e-tongue cluster nearby sour locality with inclination towards bitterness. Analysis of its quantitative data yields a PCA plot as shown in Fig. 10 where the tea concentration moves in the reverse direction with increasing PC1. This displays that the more diluted the tea, the data clusters nearer to the sour locality.

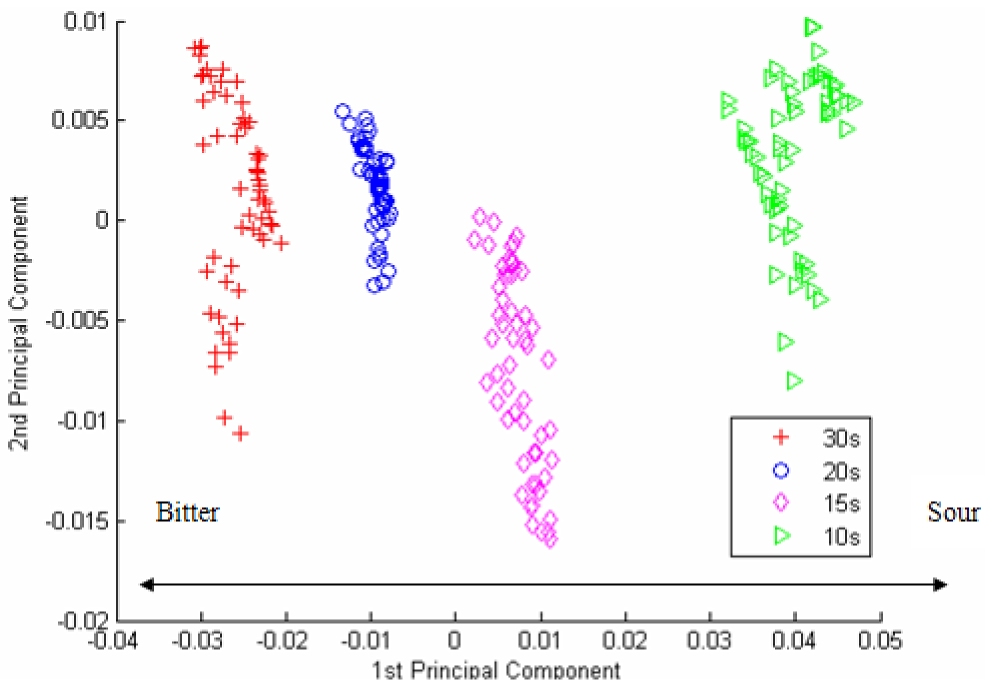


Fig. 10. Tea (Camilia Sinesis) concentrations PCA.

In line with the clustering of tea on the global map of Fig. 6 which suggests them to be of a similar group, further study on the data also yields a good qualitative clustering among the teas themselves as shown in Fig. 11. Undoubtedly, Boh Green Tea cluster away from the other three due to its difference in curing process. The significant importance is that the other 3 tea brands (at 10s steeping time) are distinguishable although they are of the similar botanical species, *Camelia sinensis*.

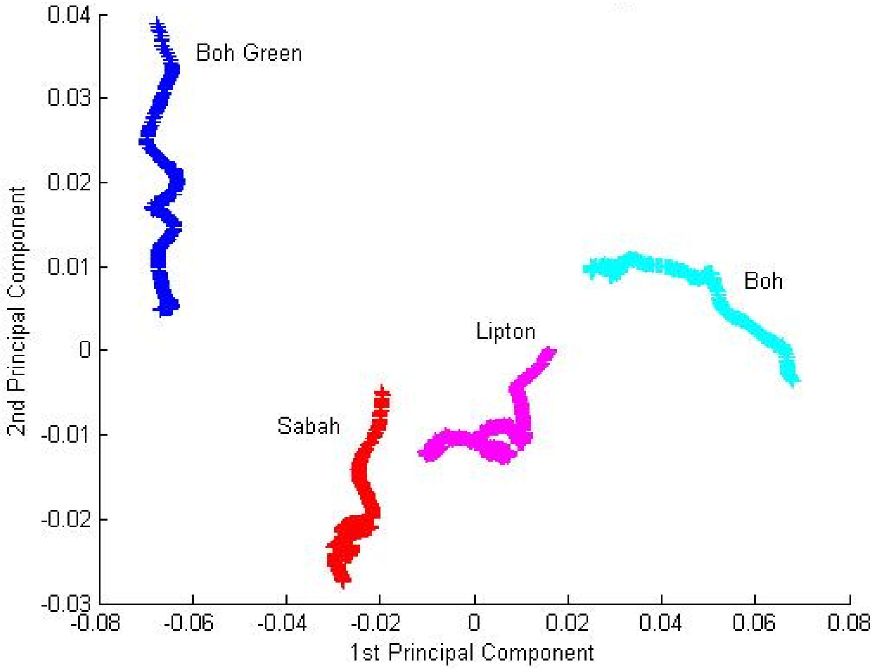


Fig. 11. PCA of all tea variations

2.3.6. Herbal Tea (*Orthosiphon staminues* Benth)

Herbal tea made from Orthosiphon leaves also called Cat Whiskas Tea has been traditionally accepted by Asean community as a remedy for kidney stone, gout, diabetics and rheumatism. Tea prepared from its leaves was tasted using the simple e-tongue. From Fig. 6, it can be deduced from the cluster location that this tea contains two taste qualities which are deliciousness and sweetness.

2.3.7. Rice

As the main source of diet for Asian, a variety of rice was tasted using our instrument. 10 g of 6 types of rice varieties/brands (fragrance, basmati, glutinous, and etc) were boiled for 30 minutes in 200 ml distilled water and left to cool to room temperature. On the global map in Fig. 6, the data clustered in sweet region and near to the umami region. Since the taste of rice clusters in between sweet and umami locality, with more inclined towards sweet locality. This suggests that rice as having similar taste to that of lactose with a little taste of deliciousness.

2.3.8. Pineapple and Honey Dew

Two varieties of on demand local fruits were tasted using the e-tongue. Ripe fruits were chosen, cut and blended. Their pure juice was tasted using the simple e-tongue and PCA analysis as shown on

Fig. 6 indicates that these fruit juices exhibit umami taste quality with honey dew being more inclined towards sweetness. Pineapple juice clustering seems to suggest that these fruit juices had their sourness suppressed by its ripening.

2.4. Other Practical Issues

In the course of this study, precautions had been taken to maintain similar test condition during each taste sampling. Apart from room temperature which is controlled by an air conditioner, electrode cleansing, magnetic stirring, electrode storage and test time cycle are the 4 issues that must be given due consideration to increase data accuracy and handling performance.

2.4.1. Cleansing

Dipping the taste electrodes into a test sample and then into another may cause contamination of the second sample. Improper cleaning may result in deposits around sensitive area and hence incorporate inaccurate readings.

In avoiding sample contamination and temporary drifts, all the sensor electrodes including reference electrode were washed before and after each taste sampling. Three cleansing method were used within the time span of this experiment with the very least is cleansing by continuous spraying of distilled water onto each electrode for 30 seconds to remove stain and residual taste samples on the electrodes. In addition to that, especially for high viscosity taste samples, the electrodes additionally cleansed by dipping them into a swirling 1 liter of distilled water at 1500 rpm for 5 minutes.

On top of that, removal of stain (such as tannin) was done by using universal solvent (75 % ethanol and 25 % distilled water). Initially each electrode is wipe using cotton cloth dipped with the solvent. Then the electrode’s sensing end was dipped into the solvent (swirling) for 60 seconds.

2.4.2. Magnetic Stirring

Occasionally magnetic stirring was used to ensure a homogenized taste samples. Nevertheless magnetic stirring was turned off during data collection process as its influence on sensor’s response is not well understood.

2.4.3. Electrode Storage/drying

The tip of the reference electrode should be kept in moist condition to ensure quick response time [4]. During the duration of this study, all electrodes were dipped in tap water whenever not in use.

2.4.4. Test Cycle Time

The response time of each electrode varies with the test sample. To ensure a proper data sampling, each taste sample tested for a minimum duration of 300 seconds per cycle. Shorter time is not recommended, the first 30 to 60 seconds of dipping response is transient (outliers) to be cropped out later using one of the GUI. Actual data for analysis are the steady state response obtained from after 60 seconds. Fig. 4 shows a typical sensor response over 300 seconds.

3. Results and Discussion

The PCA displays and results supported that the e-tongue has the ability to mimic the human tongue in differentiating the taste of various agricultural products and produced. The e-tongue system is able to perform the qualitative and quantitative discrimination.

3.1. Qualitative Discrimination

The e-tongue demonstrates the capabilities in performing the qualitative analysis. Qualitative discriminant analysis of the different taste agricultural product and produce performed to discriminate and identify the different types of the taste [15]. This research performed qualitative discriminant analysis to classify and identify the products such as honey, orange juice, lime, cat whiskas tea, rice, fish sauce, dairy food, tea and pineapple. The Fig. 6 shows that the e-tongue used and tested in this research able to discriminate among these products and produce. The PCA could plot and locate the different taste at different regions according to taste localities (Salty, Umami, Bitter, Sour and Sweet) separated distinctively.

In addition to that, the e-tongue is able to differentiate between variety type of product and produce of the same group demonstrated by Fig. 7 where the clustering of different honey is obvious. The Honey varieties separated into different cluster and the Fig. 7 shows that the honey of durian flower origins clustered closer to Sweet region whereas the honey of Malaluka, Star Fruit and Coconut clustered nearer to sour region.

In Fig. 9, the analysis done on milk souring yield responses and PCA performs and exhibits the distinction between sour milk and yogurt of different brands (possibly due to different microbes)[ref]. The PC1 and PC2 are the most significant classes containing the largest part of information about the analyzed tastes. The PCA prove clustering of the that milk souring using different brand yogurt can be separated by the e-tongue and the PCA in Fig. 9 also displays that the e-tongue able to show that the milk yogurt gets more sour by the increment in time. The display also demonstrates that the milk that souring for 15 hours located parallel to the sour milk cluster in the Fig. 9. This can be taken as a benchmark to understand the taste localities of the souring milk.

3.2. Quantitative Discrimination

Quantitative discriminant analysis is an analysis, which performs the determination of the concentration of ions in different solutions [15]. In this research the e-tongue tested to perform the determination of different taste of varies orange juice dilution. Fig. 8 displays the PCA analysis result that confirms the e-tongue is able to cluster the different dilution level for various orange brands (Brand O1 and Brand O2). Higher concentrated juice clustered nearer to sour locality while higher diluted samples clustered further. Table 2 summarized dilution details. The 75 % dilution and 100 % dilution is very much closer to each other. This result is consistent for both brands. This verifies that more diluted juice will loses sour taste gradually.

The e-tongue also able to display that the different tea concentration can be differentiated and clustered distinctively. The PCA plot in Fig. 10 attest the claim by displaying the 4 type concentration of Lipton Tea. The more concentrated the tea, PCA plots clustered to nearer the bitter region. The less concentrate the tea, the tea clustered closer to sour region. The e-tongue reveals that the more concentrated the tea, the more bitterness it acquire. Thus, e-tongue is able to perform the quantitative discrimination of different concentration level.

4. Conclusions

This paper has shown that an e-tongue can be implemented using off-the-shelf products. With 7 chalcogenide glass sensors and Ag/AgCl, this e-tongue system can perform qualitative and as well qualitative analysis of several agriculture product and produce. It is hoped that this finding will increase the interest into the study of e-tongue as an array of sensors and its possible applications especially in discriminate various taste of agro product and produce into a global map.

Together with the graphical user interfaces developed, the process of operating and analyzing an e-tongue is further simplified. The potential usage of an e-tongue as an instrument of qualitative as well as quantitative assessment had been put forward for further investigation. The results suggest that this relatively simple e-tongue exhibit an outstanding performance and is set to explore a broader horizon.

In future this research can be expanded in performing more tasting using the e-tongue on agricultural product and produce. The tasting that will be done should be an exhaustive testing in order to build a general model on agricultural based products.

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References

[1]. Anklam, E., A review of the analytical methods to determine the geographical and botanical origin of honey, *Food Chemistry*, 63, 4, 1998, pp. 549-562.
[2]. Devillers, J., M. Morlot, et al., Classification of monofloral honeys based on their quality control data., *Food Chemistry,* 86, 2, 2004, pp. 305-312.
[3]. Dias, L. A., A. M. Peres, et al., An electronic tongue taste evaluation: Identification of goat milk adulteration with bovine milk, *Sensors and Actuators B: Chemical,* 136, 1, 2009, pp. 209-217.
[4]. Hanna Instrument HI 5311 Electrode Instruction Guide.
[5]. Legin, A., A. Rudnitskaya, et al., Chalcogenide Glass Electrodes., Retrieved 15th March, 2009, from http://www.electronictongue.com/price01.html
[6]. Legin, A., A. Rudnitskaya, et al., Electronic tongue for quality assessment of ethanol, vodka and eau-de-vie, *Analytica Chimica Acta,* 534, 1, 2005, pp. 129-135.
[7]. Mottram, T., A. Rudnitskaya, et al., Evaluation of a novel chemical sensor system to detect clinical mastitis in bovine milk., *Biosensors and Bioelectronics*, 22, 11, 2007, pp. 2689-2693.
[8]. National Instrument., USB-6008/6009 User Guide and Specifications, Retrieved 15th March, 2009, from http://www.ni.com/
[9]. Pioggia, G., F. Di Francesco, et al., A composite sensor array impedentiometric electronic tongue: Part II. Discrimination of basic tastes, *Biosensors and Bioelectronics,* 22, 11, 2007, pp. 2624-2628.
[10]. Rahman, A. S. A., M. M. S. Yap, et al., A microcontroller-based taste sensing system for the verification of Eurycoma longifolia., *Sensors and Actuators B: Chemical,* 101, 1-2, 2004, pp. 191-198.
[11]. Riul, A., R. R. Malmegrim, et al, An artificial taste sensor based on conducting polymers, *Biosensors and Bioelectronics,* 18, 11, 2003, pp. 1365-1369.
[12]. Rodgers, R. S., The Ag/AgCl Reference Electrode, Retrieved 15th March, 2009, from http://www.consultrsr.com/resources/ref/agcl.htm
[13]. Toko, K. Biomimetic Sensor Technology, *Cambridge University Press,* 2000.
[14]. Toko, K., Taste sensor, *Sensors and Actuators B: Chemical,* 64, 1-3, 2000, pp. 205-215.
[15]. Vlasov, Y. G., A. V. Legin, et al., Nonspecific Sensor Arrays ("Electronic Tongue") for Chemical Analysis of Liquids, *Pure and Applied Chemistry,* Vol. 77, No. 11, 2005, pp. 1965-1983.

[16]. Vlasov, Y. G., A. V. Legin, et al., Electronic tongue, — new analytical tool for liquid analysis on the basis of non-specific sensors and methods of pattern recognition, *Sensors and Actuators B*, 65, 1-3, 2000, pp. 235-236.

[17]. Wei, Z., J. Wang, et al., Technique potential for classification of honey by electronic tongue., *Journal of Food Engineering,* 94, 3-4, 2009, pp. 260-266.

[18]. Winquist, F., P. Wide, et al., An electronic tongue based on voltammetry, *Analytica Chimica Acta,* 357, 1-2, 1997, pp. 21-31.

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Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

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